

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA)
15.3 Small Business Innovation Research (SBIR)
Proposal Submission Instructions

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IMPORTANT NOTE REGARDING THESE INSTRUCTIONS

THESE INSTRUCTIONS ONLY APPLY TO PROPOSALS SUBMITTED IN RESPONSE TO DARPA 15.3 PHASE I TOPICS.

Offerors responding to DARPA topics listed in Section 12.0 of this Solicitation must follow all the instructions provided in the DoD Program Solicitation AND the supplementary DARPA instructions contained in this section. The section/paragraph numbering in these instructions is intended to correspond with the section/paragraph numbering of the 15.3 DoD Program Solicitation (<http://www.acq.osd.mil/osbp/sbir/index.shtml>).

1.0 INTRODUCTION

DARPA's mission is to prevent technological surprise for the United States and to create technological surprise for its adversaries. The DARPA SBIR Program is designed to provide small, high-tech businesses and academic institutions the opportunity to propose radical, innovative, high-risk approaches to address existing and emerging national security threats; thereby supporting DARPA's overall strategy to bridge the gap between fundamental discoveries and the provision of new military capabilities.

The responsibility for implementing DARPA's Small Business Innovation Research (SBIR) Program rests with the Small Business Programs Office.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

**Attention: DIRO/SBPO
675 North Randolph Street
Arlington, VA 22203-2114
sbir@darpa.mil**

Home Page http://www.darpa.mil/Opportunities/SBIR_STTR/SBIR_STTR.aspx

System Requirements

Use of the DARPA SBIR/STTR Information Portal (SSIP) is MANDATORY. Offerors will be required to authenticate into the SSIP (via the DARPA Extranet) to retrieve their source selection decision notice, to request debriefings, and to upload reports (awarded contracts only). DARPA SBPO will automatically create an extranet account for new users and send the SSIP URL, authentication credentials, and login instructions AFTER the 15.3 source selection period has closed. DARPA extranet accounts will ONLY be created for the individual named as the Corporate Official (CO) on the proposal coversheet. Offerors may not request accounts for additional users at this time.

WARNING: The Corporate Official (CO) e-mail address (from the proposal coversheet) will be used to create a DARPA Extranet account. Updates to Corporate Official e-mail after proposal submission may cause significant delays to communication retrieval and contract negotiation (if selected). Additional information in section 4.0.

3.0 DEFINITIONS

3.4 Export Control

The following will apply to all projects with military or dual-use applications that develop beyond fundamental research (basic and applied research ordinarily published and shared broadly within the scientific community):

(1) The Contractor shall comply with all U. S. export control laws and regulations, including the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120 through 130, and the Export Administration Regulations (EAR), 15 CFR Parts 730 through 799, in the performance of this contract. In the absence of available license exemptions/exceptions, the Contractor shall be responsible for obtaining the appropriate licenses or other approvals, if required, for exports of (including deemed exports) hardware, technical data, and software, or for the provision of technical assistance.

(2) The Contractor shall be responsible for obtaining export licenses, if required, before utilizing foreign persons in the performance of this contract, including instances where the work is to be performed on-site at any Government installation (whether in or outside the United States), where the foreign person will have access to export-controlled technologies, including technical data or software.

(3) The Contractor shall be responsible for all regulatory record keeping requirements associated with the use of licenses and license exemptions/exceptions.

(4) The Contractor shall be responsible for ensuring that the provisions of this clause apply to its subcontractors.

Please visit http://www.pmddtc.state.gov/regulations_laws/itar.html for more detailed information regarding ITAR/EAR requirements.

3.5 Foreign National

Foreign Nationals (also known as Foreign Persons) means any person who is NOT:

- a. a citizen or national of the United States; or
- b. a lawful permanent resident; or
- c. a protected individual as defined by 8 U.S.C. § 1324b

ALL offerors proposing to use foreign nationals MUST follow section 5.4. c.(8) of the DoD Program Solicitation and disclose this information regardless of whether the topic is subject to ITAR restrictions. There are two ways to obtain U.S. citizenship: by birth or by naturalization. Additional information regarding U.S. citizenship is available at http://travel.state.gov/law/citizenship/citizenship_782.html. Definitions for “lawful permanent resident” and “protected individual” are available under section 3.5 of the DoD Program Solicitation.

4.0 PROPOSAL FUNDAMENTALS

4.6 Classified Proposals

DARPA topics are unclassified; however, the subject matter may be considered to be a “critical technology” and therefore subject to ITAR/EAR restrictions. See **Export Control** requirements above in Section 3.1.

4.7/4.8 Human or Animal Subject Research

DARPA discourages offerors from proposing to conduct Human or Animal Subject Research during Phase I due to the significant lead time required to prepare the documentation and obtain approval, which will delay the Phase I award. See sections 4.7 and 4.8 of the DoD Program Solicitation for additional information.

4.10 Debriefing

DARPA will provide a debriefing to the offeror in accordance with Federal Acquisition Regulation (FAR) 15.505. The source selection decision notice (reference 4.4 Information on Proposal Status) contains instructions for requesting a proposal debriefing. Please also refer to section 4.10 of the DoD Program Solicitation.

Notification of Proposal Receipt

Within 5 business days after the solicitation closing date, the individual named as the “Corporate Official” on the Proposal Cover Sheet will receive a separate e-mail from sbir@darpa.mil acknowledging receipt for each proposal received. Please make note of the topic number and proposal number for your records.

Notification of Proposal Status

The source selection decision notice will be available no later than **90 days after solicitation close**. The individual named as the “Corporate Official” on the Proposal Cover Sheet will receive an email for each proposal submitted, from sbir@darpa.mil with instructions for retrieving their official notification from the SSIP. Please read each notification carefully and note the proposal number and topic number referenced. The CO must retrieve the letter from the SSIP 30 days from the date the e-mail is sent. After 30 days the CO must make a written request to sbir@darpa.mil for source selection decision notice. The request must explain why the offeror was unable to retrieve the source selection decision notice from the SSIP within the original 30 day notification period. Please also refer to section 4.0 of the DoD Program Solicitation.

4.11 Solicitation Protests

Interested parties may have the right to protest this solicitation by filing directly with the agency by serving the Contracting Officer (listed below) with the protest, or by filing with the Government Accountability Office (GAO). If the protest is filed with the GAO, a copy of the protest shall be received in the office designated below within one day of filing with the GAO. The protesting firm shall obtain written and dated acknowledgment of receipt of the protest.

Agency protests regarding the solicitation should be submitted to:

SBIR/STTR Solicitation Contracting Officer

WHS/Acquisition Directorate

1155 Defense Pentagon

Washington, DC 20301-1155

E-mail: james.l.colachis.civ@mail.mil

Agency protests regarding the source selection decision should be submitted to:

DARPA

Contracts Management Office (CMO)

675 N. Randolph Street

Arlington, VA 22203

E-mail: scott.ulrey@darpa.mil and sbir@darpa.mil

4.13 Phase I Award Information

- a. Number of Phase I Awards. DARPA reserves the right to select and fund only those proposals considered to be of superior quality and highly relevant to the DARPA mission. As a result,

DARPA may fund multiple proposals in a topic area, or it may not fund any proposals in a topic area.

- b. Type of Funding Agreement. DARPA Phase I awards will be Firm Fixed Price contracts.
- c. Dollar Value. The maximum dollar value for a DARPA Phase I award shall not exceed \$155,000.
- d. Timing. The DoD goal for Phase I award is within 180 calendar days from the proposal receipt deadline. Phase I contract award may be delayed if the offeror fails to include sufficient documentation to support its cost proposal.

4.22 Discretionary Technical Assistance (DTA)

Offerors that are interested in proposing use of a vendor for technical assistance must complete the following:

- 1. Indicate in question 17, of the proposal coversheets, that you request DTA and input proposed cost of DTA (in space provided).
- 2. Provide a one-page description of the vendor you will use and the technical assistance you will receive. The description should be included as the LAST page of the Technical Volume. This description will not count against the 20-page limit of the technical volume and will NOT be evaluated.
- 3. Enter the total proposed DTA cost, which shall not exceed \$5,000, under the “Discretionary Technical Assistance” line along with a detailed cost breakdown under “Explanatory material relating to the cost proposal” via the online cost proposal.

DTA requests must be explained in detail with the cost estimate. The cost cannot be subject to any profit or fee by the requesting firm. In addition, the DTA provider may not be the requesting firm itself, an affiliate or investor of the requesting firm, or a subcontractor or consultant of the requesting firm otherwise required as part of the paid portion of the research effort (e.g., research partner).

Approval of technical assistance is not guaranteed and is subject to review of the Contracting Officer. Please see section 4.22 of the DoD Program Solicitation for additional information.

5.0 PHASE I PROPOSAL

Phase I Option

DARPA has implemented the use of a Phase I Option that may be exercised to fund interim Phase I activities while a Phase II contract is being negotiated. Only Phase I companies selected for Phase II will be eligible to exercise the Phase I Option. The Phase I Option covers activities over a period of up to four months and should describe appropriate initial Phase II activities that may lead to the successful demonstration of a product or technology. The statement of work for the Phase I Option counts toward the 20-page limit for the Technical Volume.

5.4.c.(6) Commercialization Strategy

DARPA is equally interested in dual use commercialization of SBIR project results to the U.S. military, the private sector market, or both, and expects explicit discussion of key activities to achieve this result in the commercialization strategy part of the proposal. The discussion should include identification of the problem, need, or requirement relevant to a DoD application and/or a private sector application that the SBIR project results would address; a description of how wide-spread and significant the problem, need, or requirement is; and identification of the potential DoD end-users, Federal customers, and/or private sector customers who would likely use the technology.

Technology commercialization and transition from Research and Development activities to fielded systems within the DoD is challenging. Phase I is the time to plan for and begin transition and commercialization activities. The small business must convey an understanding of the preliminary transition path or paths to be established during the Phase I project. That plan should include the Technology Readiness Level (TRL) expected at the end of the Phase I. The plan should include anticipated business model and potential private sector and federal partners the company has identified to support transition and commercialization activities. In addition, key proposed milestones anticipated during Phase II such as: prototype development, laboratory and systems testing, integration, testing in operational environment, and demonstrations.

5.5 Phase I Proposal Checklist

Complete proposals must contain the following elements. Incomplete proposals will be rejected.

- ___ 1. Volume 1: Completed Coversheet.
 - ___ a. Completed and checked for accuracy.
 - ___ b. Costs for the base and option (if proposed) are clearly separate and identified on the Proposal Cover Sheet.
- ___ 2. Volume 2: Technical Volume.
 - ___ a. Numbered all pages of the proposal consecutively. The cover sheets are pages 1 and 2. The technical volume begins on page 3.
 - ___ b. Font type is no smaller than 10-point on standard 8½" x 11" paper with one-inch margins. The header on each page of the technical proposal contains the company name, topic number and proposal number assigned by the DoD SBIR/STTR Electronic Submission Web site when the cover sheet was created. The header may be included in the one-inch margin.
 - ___ c. Include documentation required for Discretionary Technical Assistance (if proposed).
 - ___ d. The technical volume does not exceed twenty (20) pages. Any page beyond 20 will be redacted prior to evaluations.
- ___ 3. Volume 3: Cost Volume.
 - ___ a. Used the online cost proposal.
 - ___ b. Subcontractor, material and travel costs in detail. Used the "Explanatory Material Field" in the DoD Cost Volume worksheet for this information, if necessary.
 - ___ c. Costs for the base and option (if proposed) are clearly separate and identified in the Cost Volume.
 - ___ d. Base effort does not exceed \$100,000 or \$105,000 if DTA services are proposed.
 - ___ e. Option (if proposed) does not exceed \$50,000.
 - ___ f. If proposing DTA, cost submitted in accordance with instructions in section 4.22 and does not exceed \$5,000.
- ___ 4. Volume 4: Company Commercialization Report
 - ___ a. Completed and checked for accuracy. Follow requirements specified in section 5.4(e).
- ___ 5. Submission
 - ___ a. Upload four completed volumes: Volume 1: Proposal Cover Sheet; Volume 2: Technical Volume; Volume 3: Cost Volume; and Volume 4: Company Commercialization Report electronically through the DoD submission site by 6:00 AM (ET) on October 28, 2015.
 - ___ b. Review your submission after upload to ensure that all pages have transferred correctly and do not contain unreadable characters. Contact the DoD Help Desk immediately with any problems (see section 4.15).
 - ___ c. Submit your proposal before 6:00 AM (ET) on October 28, 2015. DARPA will NOT accept proposals that have NOT been submitted by the solicitation deadline.

6.0 PHASE I EVALUATION CRITERIA

Phase I proposals will be evaluated in accordance with the criteria in section 6.0 of the DoD Program Solicitation.

The offeror's attention is directed to the fact that non-Government advisors to the Government may review and provide support in proposal evaluations during source selection. Non-government advisors may have access to the offeror's proposals, may be utilized to review proposals, and may provide comments and recommendations to the Government's decision makers. These advisors will not establish final assessments of risk and will not rate or rank offeror's proposals. They are also expressly prohibited from competing for DARPA SBIR or STTR awards in the SBIR/STTR topics they review and/or provide comments on to the Government. All advisors are required to comply with procurement integrity laws and are required to sign Non-Disclosure Agreements and Rules of Conduct/Conflict of Interest statements. Non-Government technical consultants/experts will not have access to proposals that are labeled by their offerors as "Government Only".

Advocacy Letters

Please note that qualified advocacy letters will count towards the proposal page limit and will be evaluated towards criterion C. Advocacy letters are not required. Consistent with Section 3-209 of DoD 5500.7-R, Joint Ethics Regulation, which as a general rule prohibits endorsement and preferential treatment of a non-federal entity, product, service or enterprise by DoD or DoD employees in their official capacities, letters from government personnel will NOT be accepted.

A qualified advocacy letter is from a relevant commercial procuring organization(s) working with a DoD or other Federal entity, articulating their pull for the technology (i.e., what need the technology supports and why it is important to fund it), and possible commitment to provide additional funding and/or insert the technology in their acquisition/sustainment program. If submitted, the letter should be included as the last page of your technical proposal. Advocacy letters which are faxed or e-mailed separately will NOT be accepted.

Limitations on Funding

DARPA reserves the right to select and fund only those proposals considered to be of superior quality and highly relevant to the DARPA mission. As a result, DARPA may fund multiple proposals in a topic area, or it may not fund any proposals in a topic area. Phase I awards and options are subject to the availability of funds.

7.0 PHASE II PROPOSAL

All offerors awarded a Phase I contract under this solicitation will receive a notification letter with instructions for preparing and submitting a Phase II Proposal and a deadline for submission. Visit http://www.darpa.mil/Opportunities/SBIR_STTR/SBIR_Program.aspx for more information regarding the Phase II proposal process.

11.0 CONTRACTUAL CONSIDERATIONS

11.1(r) Publication Approval (Public Release)

National Security Decision Directive (NSDD) 189 established the national policy for controlling the flow of scientific, technical, and engineering information produced in federally funded fundamental research at

colleges, universities, and laboratories. The directive defines fundamental research as follows: “Fundamental research” means basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons.

It is DARPA’s goal to eliminate pre-publication review and other restrictions on fundamental research except in those exceptional cases when it is in the best interest of national security. Please visit http://www.darpa.mil/NewsEvents/Public_Release_Center/Public_Release_Center.aspx for additional information and applicable publication approval procedures.

11.4 Patents

Include documentation proving your ownership of or possession of appropriate licensing rights to all patented inventions (or inventions for which a patent application has been filed) that will be utilized under your proposal. If a patent application has been filed for an invention that your proposal utilizes, but the application has not yet been made publicly available and contains proprietary information, you may provide only the patent number, inventor name(s), assignee names (if any), filing date, filing date of any related provisional application, and a summary of the patent title, together with either: (1) a representation that you own the invention, or (2) proof of possession of appropriate licensing rights in the invention. Please see section 11.4 of the DoD Program Solicitation for additional information.

11.5 Intellectual Property Representations

Provide a good faith representation that you either own or possess appropriate licensing rights to all other intellectual property that will be utilized under your proposal. Additionally, proposers shall provide a short summary for each item asserted with less than unlimited rights that describes the nature of the restriction and the intended use of the intellectual property in the conduct of the proposed research. Please see section 11.5 of the DoD Program Solicitation for information regarding technical data rights.

11.7 Phase I Reports

All DARPA Phase I awardees are required to submit reports in accordance with the Contract Data Requirements List – CDRL and any applicable Contract Line Item Number (CLIN) of the Phase I contract. Reports must be provided to the individuals identified in Exhibit A of the contract. Please also reference section 4.0 of the DoD Program Solicitation.

Direct to Phase II

15 U.S.C. §638(cc), as amended by NDAA FY2012, Sec. 5106, PILOT TO ALLOW PHASE FLEXIBILITY, allows the DoD to make an award to a small business concern under Phase II of the SBIR program with respect to a project, without regard to whether the small business concern was provided an award under Phase I of an SBIR Program with respect to such project.

DARPA is conducting a "Direct to Phase II" pilot implementation of this authority for this 15.3 SBIR solicitation only and does not guarantee the pilot will be offered in future solicitations.

Not all DARPA topics are eligible for a Direct to Phase II award. Potential offerors should read the topic requirements carefully. Topics may accept Phase I and Direct to Phase II proposals, Phase I proposals only, or Direct to Phase II proposals only – refer to the 15.3 Topic Index to review proposal types accepted against each topic. DARPA reserves the right to not make any awards under the Direct to Phase

II pilot. All other instructions remain in effect. Direct to Phase II proposals must follow the instructions in the DARPA Direct to Phase II Solicitation Instructions.

DARPA SBIR 15.3 Topic Index

SB153-001	Soft Bio-Interfaces for Physiological Sensing and Modulation
SB153-002	GHz, Octavespanning Photodetectors for MWIR/LWIR
SB153-003	Tunable Cyber Defensive Security Mechanisms
SB153-004	High-Sample Rate Analog to Digital Converters for Reconfigurable Phased Array Applications
SB153-005	Conformal, Random Access Beam Steering for Broadband Systems
SB153-006	Medium Caliber Projectile Conformal Antenna RF Seeker

DARPA SBIR 15.3 Topic Descriptions

SB153-001 TITLE: Soft Bio-Interfaces for Physiological Sensing and Modulation

PROPOSALS ACCEPTED: Phase I and DP2. Please see the 15.3 DoD Program Solicitation and the DARPA 15.3 Phase I Instructions for Phase I requirements and proposal instructions.

TECHNOLOGY AREA(S): Biomedical, Sensors

OBJECTIVE: Develop and demonstrate clinically-viable bio-interface technologies that have mechanical properties similar to tissue, yet can interface with conventional benchtop and/or implantable electronics to form complete systems for biological sensing and modulation. Areas of interest include implantable interface technologies for neural and other biological tissue, as well as wearable biosensors and interfaces.

DESCRIPTION: There is a critical need for DoD capabilities that would provide breakthrough medical treatments for wounded warriors with post-traumatic stress disorder (PTSD), anxiety, immune system dysfunction and other DoD-relevant health issues. Regulation of neural and other biological functions via interface technologies has become increasingly enticing as a means of clinical treatment [1]. For instance, over the past several decades we have seen the emergence of neural recording and stimulation to restore sensorimotor capability and vagal nerve stimulation technologies for the treatment of epilepsy and depression. While these treatments have achieved moderate success, existing clinically approved technologies offer limited stability and precision, which significantly hinders their clinical translation. Despite recent noteworthy advancements in pre-clinical electrode technologies, existing devices suffer from reliability problems, often associated with tissue damage and/or mechanical failure of the device [2].

Even state-of-the-art interface technologies exert high mechanical strain on surrounding tissues, leading to scarring, persistent bleeding and neuronal damage. Tissue in the peripheral nervous system (PNS) has Young's Modulus of approximately 600 kPa. Traditional electrodes are manufactured using either fine metal wires, such as platinum (168 GPa), or microfabricated from silicon (180 GPa). This six order of magnitude difference in stiffness leads to a number of issues—including tissue damage, surgical attachment and relative motion—which reduce the clinical viability of these technologies. By developing bio-interfaces with kPa-scale stiffness, it would be possible to attach neuromodulation devices to the PNS without incurring these problems. Proposed implantable neural interface devices should be able to penetrate the tough epineurium of a specified nerve (e.g. vagus, ulnar), enter multiple fascicles and accommodate the range of motion that the nerve typically encounters. Wearable technologies should similarly match the mechanical properties of skin and tissue to provide robust, biocompatible solutions for biological interfacing.

This topic seeks to advance the clinical readiness of bio-interface technologies by decreasing the biomechanical mismatch between manufactured devices and biological tissue. The most established approaches in this space use polymeric substrates with embedded conductors [3]. There have been recent advances in materials that may push the Young's Modulus down even further, such as shape memory polymers that soften when inserted into tissue [4]. While these advances are important, all still use substrate materials that have a modulus greater than 10 MPa. Some early demonstrations of biologic materials such as collagen [5] have yielded crude but functional devices with kPa-scale stiffness properties. Dissolvable carrier substrates [6] have also shown promising results, but depend heavily upon the dissolution rate of the sacrificial material and leave behind tiny but stiff electrodes.

Despite these advances in materials science and device fabrication, there has been little progress towards demonstration of functional devices, much less mechanical testing with ex vivo nerve tissue or in vivo electrophysiological validation. Without this validation, promising new technologies will not be adopted by the neural interface community or medical device manufacturers.

PHASE I: Proposals to this topic should aim to develop and/or demonstrate mechanically compliant yet reliable biological interface devices that are wearable or implantable, enabling direct monitoring or modulation of biological

signals in peripheral nerves and organs. Implantable PNS-specific devices should demonstrate an ability to penetrate the epineurium and perineurium of a nerve to insert kPa-scale electrodes into individual fascicles, and to do so at a scale and precision relevant to neuromodulation therapies. These devices should include interconnects to mate with standard benchtop or implantable electrophysiology equipment. Wearable devices should provide reliable measurement of biological signals that are relevant to quantifying health physiology.

Phase I deliverables include:

Proof of concept demonstrating the feasibility of manufacturing and implementing novel soft bio-interface devices. Feasibility may be demonstrated through a variety of models, including tissue phantoms, in vitro, ex vivo, or in vivo studies. The final report must include a quantitative analysis of interface properties and mechanical characteristics. The final report should also contain detailed plans for Phase II.

PHASE II: Work in this SBIR topic should focus upon creating fully functioning interface devices suitable for chronic implantation in vivo. Performers should develop manufacturing and testing procedures to produce and verify the flexible bio-interface assembly. Devices should comprise a set of interconnects, flexible tethering leads and a compliant substrate containing a multitude of interface sites for stimulating and/or sensing neural activity (at fascicular resolution or better) or measuring biomolecules in vivo. The interface assemblies must be safe, effective and chronically stable for long-term use in animals or humans.

Phase II deliverables include:

Demonstrate the reliability and scalability of the manufacturing approach. Proposals should include plans to develop and demonstrate individual compliant devices using batch manufacturing process flows capable of producing hundreds of identical devices. Studies should characterize the morphological and physiological properties of relevant tissue to develop advanced finite element models and validate these against ex vivo experiments with the soft interface technology. Phase II efforts must also demonstrate the lifetime of the devices through Failure Mode and Effects Analysis (FMEA), including mechanical, soak and electrical testing. Finally, the devices must be tested chronically in animal models to validate sensing and modulation capability, as well as cross-talk, impedance and other relevant properties. Tissue samples must undergo histological examination to demonstrate the extent of damage incurred during application or surgical insertion as well as after chronic use.

Direct to Phase II: Existing technologies that target peripheral nerves and have demonstrated capabilities are eligible for Direct to Phase II applications.

PHASE III DUAL USE APPLICATIONS: Highly effective clinical therapies for treating disease and mental health through biocompatible neuromodulation devices.

Highly effective treatments for PTSD, anxiety, immune function, and other DoD-relevant health issues through biocompatible neuromodulation devices.

REFERENCES:

1. Famm et al. (2013), "Drug discovery: A jump-start for electroceuticals," *Nature* 496 (159-161).
2. Barrese, James C., et al. "Failure mode analysis of silicon-based intracortical microelectrode arrays in non- human primates." *Journal of neural engineering* 10.6 (2013): 066014.
3. Yoshida, Ken, Thomas Stieglitz, and Shaoyu Qiao. "Bioelectric interfaces for the peripheral nervous system." *Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE. IEEE, 2014.*
4. Ware, Taylor, et al. "Fabrication of responsive, softening neural interfaces." *Advanced Functional Materials* 22.16 (2012): 3470-3479.
5. Chen, Shuodan, and Mark G. Allen. "Extracellular matrix-based materials for neural interfacing." *MRS bulletin* 37.06 (2012): 606-613.

6. Gilgunn, P. J., et al. "An ultra-compliant, scalable neural probe with molded biodissolvable delivery vehicle." Micro Electro Mechanical Systems (MEMS), 2012 IEEE 25th International Conference on. IEEE, 2012.

KEYWORDS: biology, neuroscience, peripheral nervous system, spinal cord, neuromodulation, nerves, shape memory polymers, silicone, electrode, collagen, elastomer.

TPOC-1: Dr. Douglas Weber
Phone: 703-526-2856
Email: douglas.weber@darpa.mil

SB153-002 TITLE: GHz, Octavespanning Photodetectors for MWIR/LWIR

TECHNOLOGY AREA(S): Chemical/Biological Defense, Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Design, build, and demonstrate a high-speed (5 GHz), high-sensitivity ($NEP < 1 \text{ pW/Hz}^{1/2}$) photodetector with octave spanning responsivity in the mid-wave infrared (MWIR) and/or long-wave infrared (LWIR) spectral regions.

DESCRIPTION: There is a critical need for DoD capabilities that would provide improved detection sensitivity of threat explosives and chemical warfare species. The MWIR and LWIR spectral regions are technologically important for numerous applications including communications, environmental and industrial monitoring, thermal imaging, and chemical sensing for defense and homeland security [1]. Despite the pressing physical motivations for extending such applications to the MWIR and LWIR, the lack of suitable radiation sources and detectors in these spectral regions has resulted in applications being developed in the less favorable, near-infrared (NIR) spectral region where the telecom industry has driven the development of laser and detector technologies. The maturation of quantum cascade laser technology and the recent development of microresonator-based optical frequency comb technology [2] have changed the current and future MWIR/LWIR landscape. To fully exploit the application potential [3] of chip-scale optical frequency comb sources now under development, new high-speed, broad spectral coverage, and highly sensitive detectors are needed to replace the often bulky, cryo-cooled systems that are currently in use.

PHASE I: Design a photodetector with $< 1 \text{ pW/Hz}^{1/2}$ noise equivalent power (NEP) for operation in the MWIR (3-6 microns) and/or LWIR (6-15 microns) spectral regions. The photodetector should exhibit the specified NEP without cryo-cooling and with 5 GHz electronic bandwidth when illuminated by femtosecond to picosecond pulse trains. Room temperature operation is desirable; however, cooling and/or temperature stabilization consistent with thermoelectric cooling is acceptable. Phase I deliverables include a design review detailing expected device performance and a report presenting Phase II plans for device fabrication and characterization. The design review should specify device responsivity versus wavelength in the targeted spectral region, spanning at least one spectral octave. In addition to the NEP and electronic bandwidth, the detector active area should be defined to establish the device D^* . Detector output power and saturation properties should be addressed. The final report should describe device operational principles and limits, materials platforms and fabrication techniques, and any required supporting electronics. Experimental data demonstrating feasibility of the proposed design is favorable.

PHASE II: Fabricate and test a prototype device demonstrating the performance outlined in Phase I. Multiple devices demonstrating detector uniformity (including the potential for arrayed operation) are desirable. If not demonstrated in the prototype fabrication, a clear path toward scalable fabrication should be identified. The Technology Readiness Level to be reached is 5: Component and/or bread-board validation in relevant environment.

At the completion of Phase II, the prototype device(s) will be delivered to a laboratory of DARPA's specification for characterization and integration with optical frequency comb sources. The final device should be adequately packaged and integrated with all relevant supporting electronics for delivery to and operation by the test verification facility. Guidance for device operation should be provided for test facility personnel.

PHASE III DUAL USE APPLICATIONS: The same physical motivations underlying defense and security application of spectroscopic detection in the MWIR and LWIR spectral regions are true for numerous commercial applications of the same technology including environmental monitoring, toxic industrial chemical detection, and first responder safety and assessment. A key specification for many commercial applications is the device SWaP enabled by the elimination of cryo-cooling.

Spectroscopic detection in the MWIR and LWIR spectral regions, where fundamental molecular vibration transitions occur, combined with key atmospheric transmission windows, is critical for improved detection sensitivity of threat explosives and chemical warfare species. Active standoff detection schemes based on optical frequency comb technology, when paired with the detectors developed in this SBIR, hold great potential to exploit these fundamental physical aspects of molecular and atmospheric chemistry for improved detection limits while simultaneously achieving improved chemical selectivity.

REFERENCES:

1. D Wasserman et al., "Special issue on mid-infrared and THz photonics," J. Opt., 16, 090201 (2014).
2. C. Y. Wang et al., "Mid-infrared optical frequency combs at 2.5 mm based on crystalline microresonators," Nature Commun., 4, 1345 (2013).
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KEYWORDS: Photodetector, MWIR, LWIR, Optical Frequency Comb

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SB153-003 TITLE: Tunable Cyber Defensive Security Mechanisms

TECHNOLOGY AREA(S): Electronics, Information Systems

OBJECTIVE: Define new cyber techniques and develop technologies for automatically generating and injecting realistic vulnerabilities into large code bases for the purpose of testing and evaluating cyber security tools and capabilities, and to enable novel pedagogical tools such as customized capture- the-flag competitions.

DESCRIPTION: There is a critical DoD need for improved cyber defensive capabilities. The evaluation of cyber defensive security mechanisms is difficult and ad hoc. To compare the efficacy of different techniques, tools and technologies, analysts typically rely on synthetic benchmarks that either present a sample of existing vulnerabilities [1] or a potpourri of synthetic test cases [2]. Given the limited availability of such benchmarks, cyber security mechanisms tune their techniques to ensure success (high precision and recall). Ideally, evaluation should rely on automated mechanisms that can systematically inject realistic vulnerabilities into arbitrary software programs with enough understanding of the underlying computation to guide the evaluation of a wide range of security mechanisms

(e.g., dynamic versus static analysis techniques). To achieve such program understanding, a combination of techniques may be necessary. For example, targeted symbolic execution [3] may be used to discover program paths that could be used to generate vulnerabilities (e.g., integer overflows). The programs paths (i.e., symbolic constraints) could then be modified using information from formal methods (e.g., using SMT solvers) to generate and inject new code, at the source-level or binary-level, that is provably vulnerable (e.g., the system can prove that the generated conditions along a specific program path can lead to an integer overflow). The code may then be obfuscated, using previously learned bug patterns, to appear similar to native vulnerable code. Goal-directed branch enforcement [3] may be used to select only the relevant conditions required to reach a specific program path.

PHASE I: Conduct a feasibility study to determine innovative cyber techniques and mechanisms that are capable of automatically generating and injecting realistic vulnerabilities to real-world applications written in C or C++. Design, prototype, and evaluate a concept system for automatic generation and insertion of vulnerability test cases using a single vulnerability class (e.g., integer overflows) and support a small set of vulnerability hiding techniques (e.g., masquerade as incomplete integer overflow). The Phase I final report shall include a test methodology and success criteria for the technology.

PHASE II: Further develop the initial Phase I results to expand the scale of code that can be ingested, increase the number of vulnerability classes supported, and develop additional hiding techniques. The prototype will support multiple techniques for testing the efficacy of vulnerability detection techniques (e.g., add non-fix point loops for static analysis tools, crypto for symbolic execution engines, input checks against fuzzing). Support of at least one additional language (e.g., Java) will be explored, with initial proof-of-concept capability developed. Demonstrate the resulting prototype in accordance with the success criteria developed in Phase I. The Phase I final report shall include test results and a software prototype.

PHASE III DUAL USE APPLICATIONS: The commercial sector has concerns with the effectiveness of their cyber defensive capabilities and understands the requirement for security mechanisms that can automatically be tuned and aid in the evaluation of their cyber defensive technologies, tools, and systems to provide an effective defense against their cyber enemies. Commercial benefits include increased cyber warfare protection of critical infrastructure environments (e.g., nuclear, electrical, transportation, etc.). As part of Phase III, the developed system should be transitioned into an enterprise level tool that can be used to evaluate third-party vulnerability detection mechanisms.

The DoD and the commercial world have similar challenges with respect to maintaining the integrity of their cyber computing and communications infrastructure. Thus, the resulting cyber security techniques and technologies are directly transitionable to the DoD for use by the services within the laboratory environment (e.g., Space and Naval Warfare Systems Center (SSC) Pacific's Combined Test Bed) or a simulated operational environment.

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1. M. Zitser, R. Lippmann, and T. Leek. "Testing Static Analysis Tools Using Exploitable Buffer Overflows from Open Source Code". In Proc. SIGSOFT'04/FSE-12, pages 97–106, 2004.
2. J. Wilander and M. Kamkar. "A Comparison of Publicly Available Tools for Static Intrusion Prevention". In Proc. 7th Nordic Workshop on Secure IT Systems, pages 68–84, 2002.
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KEYWORDS: Cyber defensive security mechanisms; realistic vulnerability injection; automatically tunable cyber mechanisms; test and evaluation; cyber defense.

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SB153-004

TITLE: High-Sample Rate Analog to Digital Converters for Reconfigurable Phased Array Applications

PROPOSALS ACCEPTED: Phase I and DP2. Please see the 15.3 DoD Program Solicitation and the DARPA 15.3 Phase I Instructions for Phase I requirements and proposal instructions.

TECHNOLOGY AREA(S): Electronics, Sensors

OBJECTIVE: Develop high-sample rate, low power, analog-to-digital converters (ADCs) for elemental digital phased array antennas. By the end of Phase II of the program, the ADCs should have a demonstrated effective number of bits (ENOB) > 6 bits, conversion rate of > 40 Giga samples per second (GS/s), analog bandwidth > 20 GHz and power consumption < 500 mW.

DESCRIPTION: The ability to quickly and efficiently convert radio frequency (RF) signals to the digital domain where the underlying information can be processed using digital signal processing is a critical aspect of many DoD electronics systems. A specific example are phased array antenna systems, where high speed analog-to-digital converters (ADCs) enable the RF frequency band selection and RF beam steering to be performed using flexible and adaptive digital signal processing.

Recently, great advances have been made in high sample rate (>10 GS/s), yet energy efficient ADCs [1-3], dramatically improving the well-known Walden figure-of-merit (FOM). Yet, improvements in dynamic range, analog bandwidth and especially power consumption are needed for these converters.

To meet the needs of the DoD, this solicitation seeks high-sample rate ADCs that can meet the specifications of an ENOB greater than 6 bits, conversion rate faster than 40 GS/s, analog bandwidth greater than 20 GHz and power consumption less than 500 mW by the end of Phase II of the program. Designs may use digitally-assisted or other methods to improve performance. Especially of interest are ADC implementations that have beneficial physics based scaling in advanced CMOS technology nodes of 32 nm and below.

PHASE I: Develop, analyze and sufficiently simulate an ADC architecture with a predicted performance of:

- (1) Power < 500 mW
- (2) ENOB > 6bits
- (3) Data Rate > 40 GS/s
- (4) Analog Bandwidth > 20 GHz
- (5) FOM < 200 fJ/conversion-step

Required Phase I deliverables will include:

- (1) A report detailing the ADC architecture, design and expected performance.

PHASE II: Use Phase I analysis to design, build, and successfully demonstrate the operation of a prototype ADC for Government evaluation with the following specifications:

- (1) Power < 500 mW
- (2) ENOB > 6bits
- (3) Data Rate > 40 GS/s
- (4) Analog Bandwidth > 20 GHz
- (5) FOM < 200 fJ/conversion-step

Required Phase II deliverables include:

- (1) Report containing design, simulation, layout files and test results from 2 ADC chips.
- (2) Delivery of 2 packaged ADC chips to the government.
- (3) Any necessary GDS or equivalent layout files to allow the Government to re-fabricate the design.
- (4) A datasheet containing all the information needed for the government to characterize the chip, use the chip in an application or incorporate the data converter design and layout into a larger integrated circuit.

PHASE III DUAL USE APPLICATIONS: In the emerging 5G standard for wireless handsets, phased arrays are expected to supply the spatial filtering needed to massively increase the number of handsets supported by a single base station. Digital phased arrays would further add to the flexibility and number of simultaneous users (handsets) but further increases in ADC sample rate and bandwidth are required for digital phased arrays to emerge at 5G.

Much like the Phase III commercial communications application, high-sample rate ADCs for DoD/Military applications are of great importance. Multiple-input multiple-output (MIMO) radio frequency systems are an effective method for in-theatre communications. These ADCs are a crucial component to breaking through the limitations of current MIMO systems to create MIMO systems supporting a greatly increased number of carriers and thus communications bandwidth.

1. In order to reach the goals of future communications systems, Phase III ADC metrics are as follows:
2. Power < 500 mW
3. ENOB > 6b
4. Sample > 80 GS/s
5. Analog Bandwidth > 40 GHz

REFERENCES:

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2. N. Heath, “IBM opens the door to 400Gbps internet”, [Online]. <http://www.zdnet.com/article/ibm-opens-the-door-to-400gbps-internet/>
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KEYWORDS: ADC, A/D, analog-to-digital conversion, data converter, phased array

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SB153-005 TITLE: Conformal, Random Access Beam Steering for Broadband Systems

TECHNOLOGY AREA(S): Air Platform, Sensors

OBJECTIVE: Demonstrate a conformal, thin, broadband and rapid optical beam steering device without gimbals.

DESCRIPTION: There is a critical DoD need for a new class of broadband, random access electro-optic sensors on lightweight, airborne platforms. A conformal, thin, broadband and rapid steering beam steering device would overcome the usual, disadvantages of traditional optical systems and electro-optical devices beam steering devices, which use heavy and power-hungry gimbals and optical components making large mechanical motions. Non mechanical optical beam steering devices have been demonstrated. Most use electrically- controlled optical diffraction to steer the optical beam. These devices operate over a narrow wavelength band, since the diffraction induced steering angle depends sensitively on the wavelength of light. These narrowband devices are not suitable for broadband optical applications.

Most passive electro-optic (EO) systems are broadband. Also there are laser systems, such as femto-second pulsed lasers and supercontinuum lasers that are broadband and will allow broadband light detection and ranging (LIDAR) systems. Providing broadband beam steering for lidar and passive EO systems could enable new LIDAR capabilities using these super continuum lasers, and new passive EO systems capability.

As a baseline this effort will require operation in either the near IR wavelength region or the mid IR wavelength

region. The proposed effort should discuss extending this capability to the visible and to either the NIR region or MWIR region, whichever band is not covered by the baseline approach.

Threshold performance objectives are a 10 cm diameter aperture, a 60 degree field of steering in both angular dimensions, > 75% optical transmission efficiency, broadband operation over at least 10 percent bandwidth, beam quality no worse than 3 times diffraction limit, and < 1 msec beam steering time. It is desired to exceed these goals if possible. It is desirable to keep physical size small, with the beam steerer no deeper than the diameter of the clear aperture beam steering device. A key aspect of the approach is that the beam steering concept must be compatible with conformal windows on aircraft (i.e. windows that conform to the airframe surface). Beam steering approaches should be capable of operating bi-directionally, that is, as optical transmitters and receivers.

PHASE I: Determine feasibility of possible EO beam steering approaches and evaluate their performance. The Phase I effort should result in (1) detailed physical optics simulation of light propagation through the component(s), (2) assessment of the beam steering dynamic behavior and electrical properties, and (3) preliminary evaluation of the expected size, weight, and power consumption of a prototype implementation.

PHASE II: Demonstrate the Phase I concept via laboratory brassboard experiments, and develop a preliminary design of a device for field experiments. In Phase II, a Phase I concept will be reduced to practice and performance validated in a laboratory setting. The experiments conducted should result in empirical and/or analytic knowledge that will be used in the preliminary prototype design effort. The laboratory brassboard may not directly meet the desired threshold objectives, but should at a minimum provide characterization data and demonstrate by analysis that the performance objectives can be met. The preliminary design should focus on a demonstration system which could be utilized in a field experiment and would directly meet the performance objectives. Phase II deliverables include: (1) laboratory brassboard design, (2) report of brassboard experiment results, (3) preliminary design package for field test device.

PHASE III DUAL USE APPLICATIONS: A Phase III system could be applied to a number of commercial applications, including: 1) LIDAR measurements of wind velocities, aerosol characterization, and terrain mapping, 2) compact surveillance systems in security applications. A commercially focused Phase III effort would choose a viable commercial use and build a prototype system optimized for that application.

The DoD currently uses a large number of broadband EO systems, and active EO systems (e.g. LIDAR) are increasingly of interest as well. The use of optical systems such as these is limited by the need for a turret to house the beam director. This protrusion causes aerodynamic drag that limits range and speed of the platform. Additionally, the wake turbulence can limit the useful speed and field-of-regard regime of the sensor systems. A Phase III effort would focus on increasing the TRL level of the technology to a point that is compatible with an airborne demonstration on a relevant military air platform. The effort would include any necessary component technology development, but primarily be a detailed design, integration and test phase. Phase III would include a final test and evaluation of the beam steerer with both an active EO system and a broadband passive EO sensor.

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1. P. F. McManamon, Chair, WALTER F. BUELL, co-chair, et al, "Laser radar, Progress and Opportunities in Active EO sensing", National academy of sciences report, International Standard Book Number-13: 978-0-309-30216-6 International Standard Book Number-10: 0-309-30216-1
2. PF McManamon, PJ Bos, MJ Escuti, J Heikenfeld, S Serati, H Xie, EA Watson, "A review of phased array steering for narrow-band electro-optical systems", Proceedings of the IEEE 97 (6), 1078-1096

KEYWORDS: beam steering, electro-optics, remote sensing, conformal, optics

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SB153-006

TITLE: Medium Caliber Projectile Conformal Antenna RF Seeker

TECHNOLOGY AREA(S): Electronics, Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop conformal antennas for a medium-caliber projectile. Develop capability to survive gun launch environment. Improve target angle rate error. Improve performance of aperture-limited antennas. Demonstrate breadboard-level seeker functionality.

DESCRIPTION: The DARPA MAD-FIRES program seeks to use a medium-caliber guided projectile to engage maneuvering threats. Current projectile technologies have been demonstrated in flight maneuver, but only recently have advances in electronics and gun survivability opened the possibility of projectile-based seekers. One possible seeker type is RF seekers. Current RF systems require apertures larger than projectile diameter for target tracking in terminal engagement.

A novel approach is needed for achieving sufficient gain at small diameter to enable medium-caliber RF seekers. The alternative solution of command-guidance from ground radar places significant accuracy requirements on that radar, which becomes prohibitive for very long-range acquisitions. Optical sensors offer high accuracy, but are limited in range and require hot targets or daylight illumination. RF seekers are the primary candidate for maturation.

DARPA seeks a novel antenna and seeker approach that will allow successful antenna integration on a medium-caliber projectile. The antennas must reside within the outer mold line of a medium-caliber projectile and survive gun launch and ballistic fly out. The antenna should provide sufficient gain in the forward direction to track targets during fly out and terminal engagement. The antennas must support accurate measurement of line of sight to target for terminal phase guidance.

This RF seeker shall provide a higher Pk than existing approaches, which will benefit the DoD and the warfighter by fewer shots required per target, lower cost per intercept, and greater survivability of the defended asset.

PHASE I: Develop and design antennas for the MAD-FIRES projectile, simulate performance for configuration selection, and trade size and shape against performance to allow antenna selection trades for projectile integration. Analysis should reveal the antenna performance characteristics in a relevant environment across frequency and angle of approach to target. The proposer shall further the proof of concept study by evaluating component survivability during launch up to performing shock testing to simulate various representative launch loads. A final proposed design with a discussion of trades and details of expected performance is expected at the completion of Phase I.

PHASE II: Complete a detailed antenna design for the MAD-FIRES projectile culminating in a critical design review of the concept. Upon successful review, fabricate prototype antennas for potential live-fire testing. Measure performance of seeker in hardware demonstration and use results to update error model and refine algorithm, as necessary. Phase II deliverables will include: 1) fabricated prototype seeker and platform mock-up, 2) quantified results of performance measurements taken during hardware demo, and 3) updated/validated seeker error model, suitable for use in 6DOF simulations. The Phase II final report should describe the seeker design, the measured performance and the final seeker error model.

PHASE III DUAL USE APPLICATIONS: Small, survivable, lightweight antennas and receiver hardware will enable unique commercial applications for systems requiring highly directional and robust receiver solutions such as

commercial satellites, relocatable communications nodes, and vehicle ranging sensors for autonomous vehicles. Inclusion on small Unmanned Aerial Vehicles (UAVs) would create selectable, directional datalinks improving link margin for mesh networking and reducing power requirements for downlinks. This technology provides design flexibility to all size constrained systems such as UAVs and satellites. The ability to position antennas longitudinally (lengthwise) while achieving the same performance as a traditional front facing antenna provides many more options for antenna placement and orientation to optimize overall miniaturization and compact system design.

Military applications will focus on the DARPA MAD-FIRES platform, supporting the government system analysis that will inform the MAD-FIRES contractor concepts. Additional applications will include C-RAM and strategic defense missions, including adaptations for projectile and missile host platforms.

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2. EXACTO Demonstration Video: <https://www.youtube.com/watch?v=vX8Z2MDYX3g>

KEYWORDS: Medium caliber projectile, ballistics, guided bullet, guided round, target intercept, RF seeker, miniature seeker, precision-guided munition

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